WS15-D04

3D DAS-VSP Processing and Learning - Velocity Diagnosis and Update for Seismic Imaging Improvement

H. Wu (Shell International E & P Co.), P. Wills (Shell International E & P Co.), Y. Li* (Shell Exploration & Production Co.), W. Wong (Shell Exploration and Production Co.), B. Hewett (Shell Exploration & Production Co.) & Z. Liu (Shell Exploration & Production Co.)

SUMMARY

In 2012, Shell acquired its first dual-well 3D DAS-VSP (Distributed Acoustic Sensing - Vertical Seismic Profiling) data concurrently with an OBS survey in a deep water environment in the Gulf of Mexico. A work flow was developed to process the 3D DAS-VSP data and use the VSP first arrival times to diagnose the velocity models which were derived from previous surface seismic surveys for selecting a suitable initial velocity model to be updated with the travel time tomography inversion. The VSP diagnosis method was applied again to the updated VTI-inversion model to ensure the velocity updating effort is in the right track. Both DAS-VSP and OBS data were migrated with the initial VTI velocity model and the updated VTI-inversion model. It is found that both borehole and surface seismic images generated with the VTI-inversion model are significantly improved from those obtained with the initial model, especially for the seismic amplitudes at the target event. In this paper, we will share our processing procedure and some learning from our practices of processing marine 3D DAS-VSP data. Processing results from borehole seismic data acquired in Well 1 will be presented as examples.

Introduction

With advances of fibre seismic observation technologies, distributed acoustic sensing (DAS) systems using the fibre optical cable have played more important roles in the borehole seismic monitoring and imaging. In 2012, Shell acquired its first 3D dual-well DAS-VSP (Vertical Seismic Profiling) simultaneously with an OBS (Ocean Bottom Sensor) survey in a deep water environment (Mateeva et al., 2013) in the Gulf of Mexico (GOM). The fibre optic cables were installed on tubing and cover nearly the entire length of the two wells (Figure 1). The data acquisition consists of more than 35,000 surface OBS shots with the shot grid spanning an area of about 9 km x 10 km at nominally 50 m x 50 m shot spacing and about 600 DAS channels with 8 m spacing between "sensors" for each of the 2 wells. The DAS channels span a depth from sea bottom of 889 to 4929 m.This DAS-VSP survey provides rich borehole seismic data to diagnose and update the velocity models generated from surface seismic surveys and examine the effects from model updating on improvements of both borehole and surface seismic images. Due to favourable source-receiver geometry distribution, we will focus on the processing and analysis of DAS-VSP data acquired at Well 1 in this study.

Velocity Model Diagnosis and Update

Processing of 3D DAS-VSP data acquired at Well 1 involved removal of bad data and noise, picking first arrival times, shot scaling for amplitude balance, Wiener filtering for spectrum widening, separation and enhancement of up- and down-going wave-fields, and finally RTM depth migration up to 45 Hz. Given the data size, effectively picking of the first arrival times is a great challenge. A semi-automatic picking method is developed using the model predicted times to limit the search time windows and the resulting picks are carefully QC'd manually. The huge amount of the picked first arrival times from this DAS-VSP data provides a good opportunity to quantitatively diagnose and update velocity models (Li & Hewett, 2013) generated from the surface seismic surveys using the time differences between observed and model calculated VSP arrival times (T_{obs} - T_{model}). We first use our diagnosis method to select the best initial velocity model to be updated (Figures 2a, 2b, & 2c). A travel time tomography inversion is carried out with the initial VTI model to produce an updated VTI-inversion model. We apply our diagnosis method again to the updated model and find a significant improvement in the tomography updated velocity model as shown in Figure 3.

Borehole and Surface Seismic Imaging Improvements

The separated up-going waves from the 3D DAS-VSP data at Well 1 as well as the processed OBS were migrated with both initial VTI model and updated VTI-inversion model. The OBS migration image gathers along the gg' cross-section, generated with the initial and the updated velocity models, demonstrate that the VTI-inversion updated model indeed helps to flatten the reflection migration gathers. Depth slices of seismic amplitudes of OBS migration images at the target event using both initial and updated models are shown in Figures 4a and 4b, indicating that significant improvement of high amplitude energy concentration occurs around the well path of Well 1 using the updated model. The seismic amplitudes from DAS-VSP depth migrations with the both models shown in Figures 4c and 4d also demonstrate that DAS-VSP migration with the updated model provides much better borehole seismic image of the target event.

Conclusions

We have demonstrated that the 3D DAS-VSP concurrently acquired with the OBS survey in the GOM can be processed to diagnose and update the velocity models derived from surface seismic surveys and significantly improve seismic images with the updated velocity model. Re-diagnosis of the update velocity model ensures that the velocity updating is the right direction and provides useful clues for further updating. OBS and DAS-VSP depth migrations with both initial and updated velocity models show significant improvements of the seismic amplitudes at the target event. Further velocity updating with the joint tomography-inversion of OBS and VSP first arrival times, including VSP reflection times is a challenge but achievable task in near future.

Acknowledgements

The authors thank Shell Oil Company for permission to publish this paper.

References

Mateeva, A., Mestayer, J., Yang, Z., Lopez, J., Wills, P., Roy, J. and Bown, T. (2013) Dual-Well 3D VSP in Deepwater Made Possible by DAS. 83rd *Annual SEG Meeting*, Expanded Abstracts.
Li Y. and Hewett B. (2013) Diagnosis of Surface Seismic Velocity Model Uncertainty using VSP Arrival Times and Angles. 83rd *Annual SEG Meeting*, Expanded Abstracts.

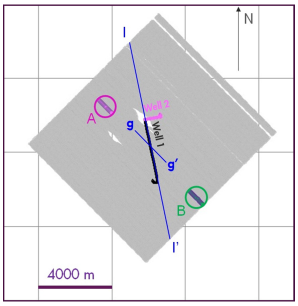

Figure1 *Map view showing survey geometry of DAS-VSP and OBS in the Gulf of Mexico. Black and pink triangles are receivers in wells 1 and 2. Gray dots are OBS shots. Two circles at A and B represent 20 seismic sources at each location used to diagnose the velocity models.*

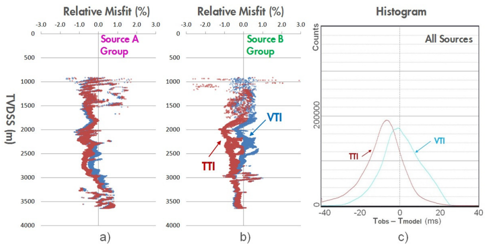

Figure 2 *Diagnose and select initial velocity models. a) and b) are relative misfit depth profiles for VTI and TTI models. c) Histogram of time differences (Tobs –Tmodel) for the VTI and TTI models.*

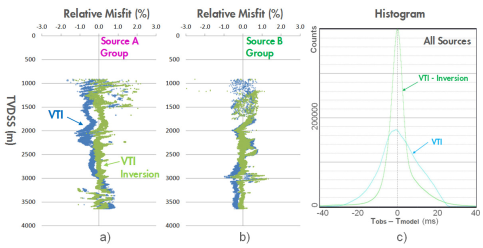

Figure 3 *Diagnose velocity models before and after the Travel Time Tomography Inversion. a) & b) are relative misfit depth profiles for VTI and VTI-inversion models. c) Histogram of the time differences (Tobs – Tmodel) for the VTI and VTI-inversion models.*

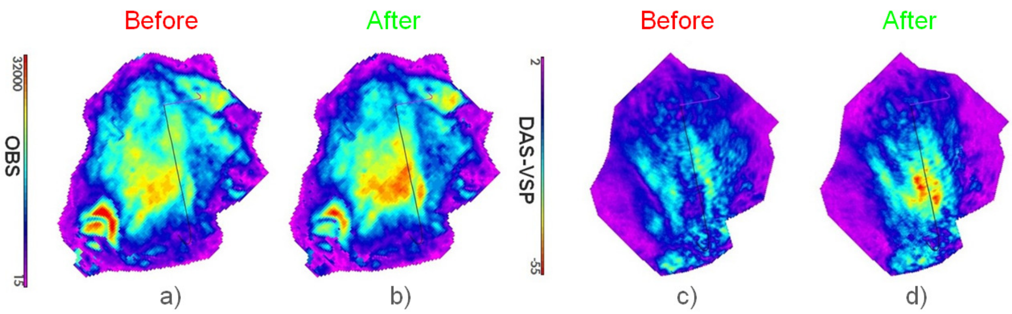

Figure 4 *Map views of seismic amplitudes at the event from the OBS and DAS-VSP migration images. a) & c) are generated with the VTI model and b) and d) are migrated using the VTI-inversion model after travel time tomography inversion of DAS-VSP data.*